Immediate prosthesis fitting and comprehensive rehabilitation following lower limb amputation – the most important components of physiotherapy

Szybkie protezowanie i kompleksowa rehabilitacja po amputacji kończyn dolnych – najważniejsze składniki postępowania fizjoterapeutycznego

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Key words

Amputations, prosthesis fitting, physiotherapy, stump care, bandaging, prostheses, integration

Abstract

In this paper, a model of rehabilitation and immediate prosthesis fitting following lower limb amputation was presented. Advantages of amputee's treatment in a specialised centre for comprehensive rehabilitation, beginning with the first days of hospitalisation up to the point of achievement of optimal physical fitness and independence allowing hospital discharge, were emphasised. Psychological support offered to the patients was addressed. Peculiar character of physiotherapist's range of activity both in patients' rehabilitation and prosthesis fitting was presented. The role of early prosthesis application was emphasised by presenting successive stages of fabrication of the temporary and then the definitive prosthesis, from taking the measure, formation of stump positive and, subsequently, of particular components of the prosthesis, up to its regulation, definitive assembly of all parts and finishing. Examples of prosthetic solutions for instrumentation of irregularly shaped stumps were described and shown. The essence of correct stump positioning for preventing contractures as well as its bandaging to combat post-operation oedema, to reduce pain, accelerate post-surgery wound healing and stump formation was denoted. Successive stages of patient's mobilisation, assuming the erect posture and gait learning, including walking on a stairway, uneven ground and overcoming obstacles, as well as types of the performed kinesitherapeutic exercises and most frequently used physiotherapeutic procedures were distinguished. Forms of sport-recreational treatment and integration activities aiming at patient's best possible preparation for independent life were discussed. Additionally, the spectrum of ergotherapist's activities, including patient home visits to adjust household conditions to new patient's needs, was presented. Finally, based on a case report of a patient in advanced age with prolonged stump healing, the whole process of immediate prosthetic fitting and comprehensive rehabilitation, starting with the day of admission to the rehabilitation centre up to the point of definitive application of the prosthesis and achievement of complete independence, was described.

Słowa kluczowe

Amputacje, protezowanie, fizjoterapia, pielęgnacja kikuta, bandażowanie, protezy, integracja

Streszczenie

W pracy przedstawiono model rehabilitacji i szybkiego protezowania po amputacji kończyn dolnych. Wskazano zalety prowadzenia usprawniania chorego po amputacji w wyspecjalizowanym ośrodku kompleksowej rehabilitacji, począwszy od pierwszych dni hospitalizacji, aż do momentu uzyskania optymalnej sprawności fizycznej i samodzielności, pozwalających na jego opuszczenie.

Uwzględniono oferowane pacjentom wsparcie psychologiczne. Przedstawiona została specyfika zakresu działań fizjoterapeuty zarówno w rehabilitacji, jak i protezowaniu pacjentów. Wskazano rolę wczesnego protezowania, prezentując kolejne etapy powstawania protezy tymczasowej, a później definitywnej, począwszy od pobrania miary, wykonania pozytywu kikuta, a następnie poszczególnych elementów protezy, aż do zakończenia jej regulacji, połączenia definitywnego wszystkich jej części i wykończenia. Opisane i pokazane zostały przykładowe rozwiązania protetyczne dla zaaparatowania kikuta o nieregularnym kształcie. Zaznaczono istotę prawidłowego układania kikuta w profilaktyce przeciw powstawaniu przykurczy, oraz jego bandażowania, w walce z obrzękiem pooperacyjnym, w celu ograniczenia dolegliwości bólowych, przyspieszenia gojenia się rany pooperacyjnej i formowania kikuta. Wyszczególnione zostały kolejne etapy uruchamiania pacjenta, pionizacji i nauki chodu, wraz z poruszaniem się po schodach, nierównym podłożu i pokonywaniem przeszkód oraz rodzaje wykonywanych ćwiczeń kinezyterapeutycznych i najczęściej stosowanych zabiegów fizykoterapeutycznych. Omówiono formy prowadzonych z pacjentami zajęć aktywności sportowo-rekreacyjnej i działań integracyjnych, mających na celu jak najlepsze przygotowanie pacjenta do samodzielnego życia. Dodatkowo przedstawiony został zakres działań ergoterapeuty, z uwzględnieniem przeprowadzanych przez niego wizyt w domu pacjenta, w celu przystosowania warunków mieszkaniowych do nowych potrzeb chorego. Na końcu, na przykładzie opisu przypadku pacjenta w zaawansowanym wieku, z długo gojącym się kikutem, pokazano cały proces szybkiego protezowania i kompleksowej rehabilitacji od dnia przyjęcia do ośrodka rehabilitacji aż do momentu definitywnego zaprotezowania. i uzyskania pełnej samodzielności.

Introduction

Amputations are performed in patients with advanced pathological changes due to vascular, diabetic, neoplastic, posttraumatic (most frequently as a result of traffic and occupational accidents or suicidal attempts) or hospital infections-related factors. Injuries caused by animal bites (e.g. monkeys, sharks, crocodiles) leading to amputations also occur. In young persons, traumas (mainly motorcycle accidents or occupational accidents), neoplastic diseases or infections are the primary causes of amputations[1].

There are no explicit data on the number of performed amputations. According to de Angelis et al.[2], there is 1 amputee among 1000 inhabitants in France, and 6000 amputations are performed yearly, with 70% thereof due to vascular causes, of which 85% of patients are above 60 years of age. Among patients with vascular disorders, 1500 above-knee and 2000–3000 below-knee amputations per year are performed[2].

Other sources report that 100 000 amputees and 8000–9000 new lower limb amputations are currently registered yearly in France. Twenty three percent of amputations are caused by injuries. Pathologic conditions cause approximately 80% of amputations; 65% of them affect persons above 65 years of age[3].

Arteriopathy is present in 90% of patients above 60 years of age[4]. Over half of vascular amputations is performed in diabetic patients (50–60%)[4]. Number of people with diabetes in France is 50 000 – 60 000 per year, where a half of these patients require hospitalisation[5]. It is estimated that limb amputations are performed in approximately 15% of diabetic patients, and re-amputation index is 56% within 5 years[6]. These patients constitute 30–40% of all amputees in France, of whom only 6% had limb prosthetic fitting, which may be explained by poor stump healing[7]. Amputations in persons below 50 years of age are rare, amputees' mean age is approximately 70 years, and these operations are more frequently performed in males[7].

In Poland, according to Nejman[8], approximately 70% of lower limb amputations are vascular amputations, with arteriosclerosis obliterans-induced ischaemia being the most frequent aetiology (approximately 80% of vascular amputations), further causes include: diabetes with accompanying vascular complications, Buerger's disease, embolism and thrombosis[8,9].

Another group of amputees comprises patients with inborn amputations, that is, according to Cailleux[10], inborn limb hypoplasia resulting from damage or impaired development of the embryo. The majority of abnormalities determining limb hypoplasia occur between the 4th and the 6th week of intrauterine life[10].

Peculiarity of comprehensive therapy

Limb amputation is a traumatic experience. Necessity of its performance is decided upon to save patient's life or inhibit progression of pathological changes within his organism. The first 2 weeks following the amputation procedure are most difficult for the patient. In the early period of time, amputees may experience particularly intensive emotional states, which is unavoidable and significantly more pronounced in cases of posttraumatic amputations. Apart from the complete hospital care, psychological and/or psychiatric support, as well as very early rehabilitation are extremely important.

Sending the patient to a specialised comprehensive rehabilitation centre (prosthesis fitting, kinesitherapy with physiotherapy, ergotherapy, sport and recreational activities, psychotherapy, integration with the environment) seems to be more advantageous for the amputee at this stage of rehabilitation than management restricted to technical aspects involving exclusively prosthetic fitting of the patient as a part of ambulatory care (single checking and adjustment of the prosthesis) and, optionally, follow-up visits without any possibilities of immediate intervention in cases of complications.

Medical staff of the department, where the amputation was performed, should refer the patient to a rehabilitation centre immediately after discharge from the hospital. A rehabilitation centre located close to amputee's home should be chosen because of a frequent need of help provided by the centre to perform necessary modifications of the prosthesis and its cyclic replacement in the later course. As Przeździak[11] cites: "…during the World War I, a French surgeon, F. Martin, performed early prosthesis fitting and found successors of his work…" and further quotes French authors, Villaret and Roederer, as of 1923: "…prosthesis fitting should be performed in the hospital, as early as possible, even before complete stump healing…"[11].

French centres have been following the principles of comprehensive treatment, intensive rehabilitation and immediate prosthesis fitting. The Institute Robert Merle d'Aubigne in Valenton, close to Paris, is one of such centres. It is one of a few rehabilitation departments in Europe, where physiotherapist's role involves both rehabilitation treatment and prosthesis fitting. Each year, approximately 3000 amputees are admitted to this centre and approximately 1800 of them are fitted with prostheses. The centre has been active for nearly 40 years, which guarantees its substantial experience in prosthetics and rehabilitation. Functional framework of the centre comprises appropriately prepared therapeutic group of physicians, physiotherapists, nurses, psychologists, ergotherapists and physical education instructors[1] (fr. *educateur sportif*), as well as a hospital part, consisting of 3 wards with full medical and psychological care (each with 30 beds) and an outpatient clinic, prosthetic atelier, rehabilitation part, including: a hall for individual physiotherapeutic exercises with physical therapy, a hall for march learning, gymnastic hall of standard dimensions, with a possibility of playing team games and climbing learning on a custom designed artificial wall, swimming pool, balneotherapy, ergotherapy and a service department for patients, including a barber shop. The building of the centre connects directly to a park that perfectly serves rehabilitational and recreational purposes.

Hospitalisation in the rehabilitation centre

Hospitalisation in the rehabilitation centre is initiated as soon as possible following the amputation, usually after approximately 2 weeks, and sometimes as early as on the 7th day after the operation, with patient's clinical status and possibilities of prosthesis fitting taken into account.

It is estimated that approximately 50% of patients are successfully fitted with prostheses (prosthesis fitting and walking), which is related to the fact that nearly half of the amputees are excluded from the planned attempt of applying prostheses due to post-surgery complications (several re-amputations, poor general condition, progression of the disease, uncontrolled diabetes, significant overweight, marked joint deformations resulting from rheumatic diseases, ischaemia of the contralateral limb preventing its loading, plegia or paresis of the extremities, lack of logical contact with the patient)[9]. There is no determined age limit for prosthetic fitting. Qualification of a patient for prosthesis application depends primarily on the stump status and the cardiovascular system function. Efficient prosthesis fitting is possible even in the 10th decade of life.

Amputees are treated in the rehabilitation department for 2–3 months (see: Case report); however, if their general condition, especially physical fitness, still does not allow discharge home, their stay in the centre is prolonged. Unfortunately, it happens that a patient has to return to the hospital ward because of worsening health status, poorly healing stump or a necessity of re-amputation.

[1] Specialists of physical education appropriately prepared for working with patients participate in the therapy; e.g. in France, these are separately trained persons with a licence to conduct recreational-sport activities with handicapped persons. Their obligations include conduction of fitness training and water exercises, organising recreational-integration trips outside the institute, e.g. excursions to a cinema, restaurant, shopping centre, recreation parks, which aim at adaptation to novel conditions, changed after the amputation.

Post-operation care of the wound, the stump and the non-amputated limb

Post-operation wound healing is most problematic in patients with vascular diseases-related amputations. In vascular diseases, the amputation is sometimes performed using a surgical technique that involves leaving a so-called open stump. Refraining from suturing the post-operation wound prevents possible ischaemia and necrosis of the tissues located in the distal stump, which might be induced by the pressure exerted by the post-operation suture, possibly hampering stump healing. Owing to the efficacy of this method, it is often possible to preserve a longer stump and the knee joint, which is extremely important for proper prosthesis fitting and restoration of physical fitness.

It should also be mentioned that, with the development of surgical techniques, procedures of by-pass grafting in the lower limbs are more and more frequently conducted, which allows performing amputations in a more distal segment[12]. This is not unimportant for the maintenance of patient's best possible functional skills. The higher the level of the amputation, the more significant is the impairment of the amputee's motor function and the greater the effort and energetic expenditure during locomotion. It was demonstrated that energetic consumption increases by 9% during walking with calf prosthesis and by as much as 45% during walking in thigh prosthesis as compared to the physiological gait, and increases with amputee's age[13]. Increased energetic cost of walking in patients with lower limb amputations can be explained by a significant shift of the centre of gravity during the gait[14].

Initially, dressing of the stump is performed daily, which enables simultaneous assessment of the post-operation wound status and healing rate. Each time, the dressing is **obligatorily** finished by bandaging the stump (Figure 1).

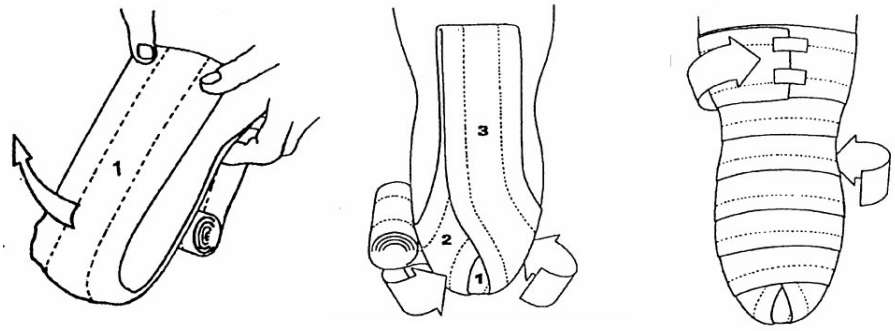


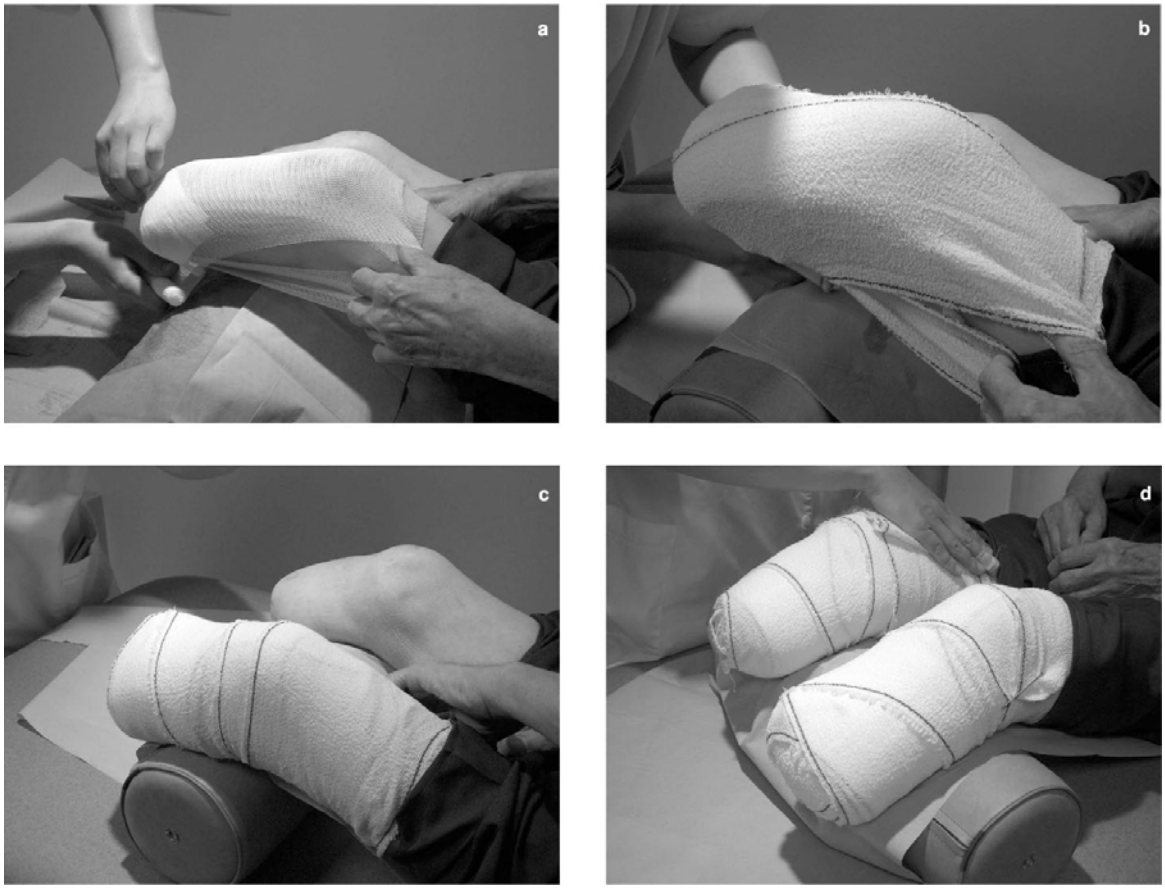
Figure 1

An example of bandaging the shank stump (successive stages) (with permission from the Artificial Limb Centre (CRA – Centre de Reeducation et d'Appareillage), Institut Robert Merle d'Aubigne, Valenton, Ile-de-France)

The strictly determined stump bandaging system allows preventing and reducing oedema, alleviating pain, accelerating wound healing, and prepares the stump for subsequent prosthesis fitting by forming it[15]. The stump should be bandaged several times a day, i.e. not only at the end of each dressing, but also after exercises and each detachment of the prosthesis (including detailed skin observation: possible skin abrasions, reddening or cyanosis, dripping from the wound). This should be absolutely complied with (Picture 1 a-d). Each patient is appropriately trained in bandaging his stump as early as during the first days of hospitalisation. Stump bandaging is indicated during patient's whole lifetime. As soon as the stump is formed, it is possible to replace the bandage with an elastic stocking.

When the erect posture is assumed and the prosthesis fitted early, the commonly used stump hardening seems unnecessary. The role of hardening exercises and procedures is taken over by gait training with the prosthesis, conducted for even several hours a day.

In patients with diabetes, a problem of contralateral foot and/or shank ulceration occurs or already coexists relatively frequently. Patients with this disease are subjected to frequent vascular and dermatological consultations since the beginning of their stay in the rehabilitation centre. Especially for these patients, pedicurist visits (in order to prevent damage to the skin of the foot by deformed nails) are scheduled and – in cases, where changes within the foot are present – special, individually designed, made to measure, soft orthopaedic shoes without internal seams are manufactured.



Picture 1 a-d

An example of bandaging shank stumps: with a dressing bandage (a) and subsequently elastic bandage (b-d) (with permission from the Artificial Limb Centre (CRA – Centre de Reeducation et d'Appareillage), Institut Robert Merle d'Aubigne, Valenton, Ile-de-France)

Pains and other phantom sensations and the rehabilitation

The vast majority of the amputees experience phantom pains or other phantom sensations of a very different character and intensity. There are, however, reports demonstrating that the prevalence of these phenomena does not depend on patient's sex, age or amputation cause[1].

Phantom sensations are a common phenomenon among the amputees. Sometimes, sensation of the "phantom" is so strong and real that the patient may suffer injury, e.g. during a night-time fall from his bed, when – getting out of bed to use the toilet – the patient forgets that his one limb is now shorter. Such problems did happen to patients in the centre. Not infrequently, during the exercises, the amputee asks to immediately stop them, because his phantom sensation is markedly enhanced at this particular point of time (e.g. sensation of a powerful dorsiflexion of the non-existing hallux or intensive paraesthesia in the non-existing limb). At this stage, e.g. trials of active flexion and extension movements in the knee joint (in cases of shank amputations) sometimes result in alleviation of these sensations and enable resuming the rehabilitation.

Phantom pain is a pain experience referring to the area of the lacking extremity. Its prevalence is estimated for 72% to 80% immediately after the operation and for 3 to 10% after several following years[16]. Proximal amputations are more frequently associated with phantom pain than the distal amputations[16]. They occur in approximately 80% of amputees[17].

According to Boffy et al.[1], the incidence of phantom pains in the population of amputees is increasing. They are experienced by approximately 2/3 of the amputees (68%); and the mean pain intensity in the 200 patients examined by Boffy was 5.6 in a 0–10 point visual-analogue scale (VAS)[1].

Prosthesis fitting

The aim of early prosthesis fitting involves possibly earliest mobilisation of the patient enabling best possible restoration of physical fitness and independence. Immediate prosthesis application is also equally important for the prevention of contractures. According to Wasiak[9], early prosthesis fitting and rehabilitation treatment doubles patient's chances of avoiding flexion contracture in the knee joint of the operated extremity following trans-tibial amputations[9].

Prosthesis fitting is initiated as soon as the status of the limb stump allows performing this procedure, usually by the end of the third week after the surgery. For fitting the prosthesis, it is not required that the post-operation wound completely heals (Picture 2)[15]. It frequently happens that complete stump healing occurs at the point of time, when the amputee already starts walking with the definitive prosthesis (see: Case report).

Picture 2

A non-completely healed stump that may already be fitted with the prosthesis (with permission from the Artificial Limb Centre (CRA – Centre de Reeducation et d'Appareillage), Institut Robert Merle d'Aubigne, Valenton, Ile-de-France)

For fitting the patient with prosthesis, it is important that there is a full range of motion in the hip and knee articulations (after a trans-tibial or lower amputation), absence of flexion contracture and proper stump formation[18].

Exact timing of initiation of first prosthesis fitting procedures depends on the attending physician's decision.

The first phase of preparing the prosthesis involves exact measurement of the stump (circumferences and length) performed by the physiotherapist and marking the most important sites on the operated extremity using a dermographic pencil. If the stump has not healed, the mesaurements are performed on the dressing secured from possible contamination and infection with a foil. After having finished the measurements, the physiotherapist prepares a plaster cast of the stump (using plaster bandages for this purpose) that is subsequently delivered to the technician for complete plaster filling. In patients with haired limb, the stump should be smeared with vaseline, which facilitates pain-free detachment of the hardened plaster cast. When the cast is ready, its precise processing begins (rubbing and smoothing its surface following the previously marked points) (Picture 3) to obtain as detailed anatomical positive model of the stump shape as possible (Picture 4). After this process is terminated and dimensions of the positive model and the stump precisely checked for compatibility, a foam insert and a funnel of the temporary prosthesis are produced.

Picture 3

Positive model of a stump at an early stage of fabrication (with permission from the Artificial Limb Centre (CRA – Centre de Reeducation et d'Appareillage), Institut Robert Merle d'Aubigne, Valenton, Ile-de-France)

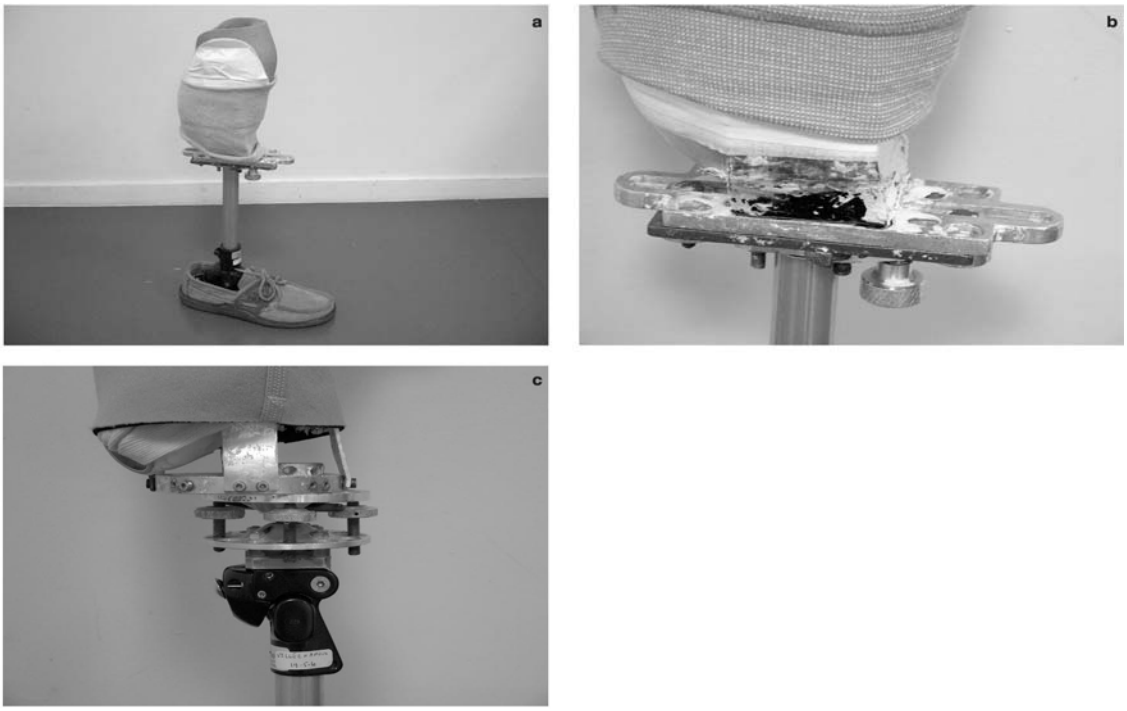
Picture 4

Fabricated positive model of a stump, ready for the initiation of prosthesis' insert and funnel production (with permission from the Artificial Limb Centre (CRA – Centre de Reeducation et d'Appareillage), Institut Robert Merle d'Aubigne, Valenton, Ile-de-France)

The temporary prosthesis may be made of plaster, not only because of low costs of this material, but, first of all, because of the necessity to perform multiple modifications of the prosthesis funnel following changing dimensions and shape of the stump resulting from oedema reduction and formation of the muscle system in the operated extremity. In cases, where the stump has not yet healed, a cavity may be hollowed on the internal surface of the funnel at the level of stump wound in order to reduce the pressure, and, if necessary, an aperture is cut in the funnel for a complete relief of the unhealed stump surface. In this way, the amputee may start learning to walk with the temporary prosthesis relatively soon after the amputation surgery and thus regain more complete fitness within possibly shortest period of time.

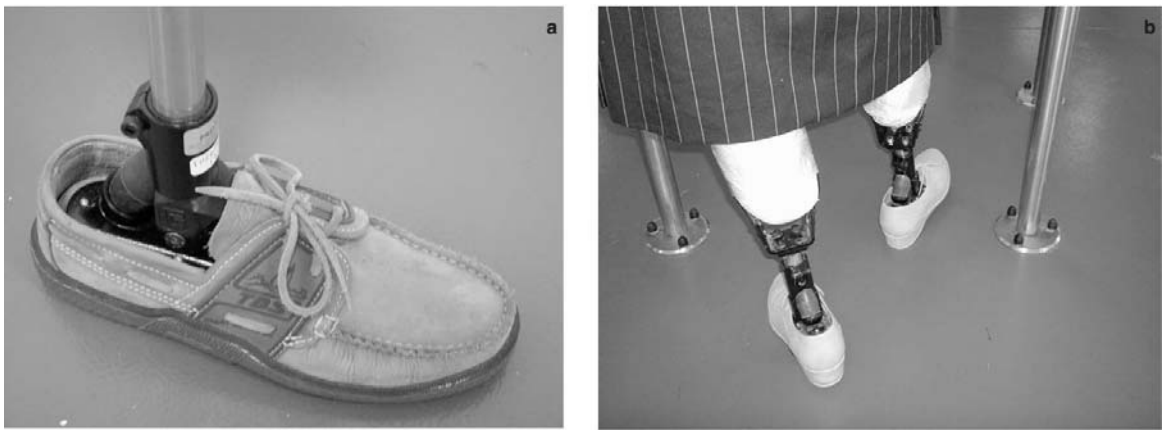
Following the preparation of the temporary prosthesis funnel, the physiotherapist fits it on the patient's stump (tightening the funnel or loading the limb – examines sensitivity of the stump to pressure and checks for a presence of the pumping effect that would indicate incorrectly fitted funnel length in relation to the stump length or too large funnel circumference). When the physiotherapist considers the funnel to be well fitted and the patient feels well in it (the funnel is not too tight and does not rub – the information obtained from the patient as well as from control observation of stump appearance after funnel detachment), montage of the temporary prosthesis is initiated with proper assembly of its

all components in relation to each other. After this phase of prosthesis fabrication is finished, the physiotherapist fits it on the patient, which is also associated with the patient assuming the upright posture for the first time. The next, very important stage involves appropriate and detailed prosthesis regulation (in all planes of movement) according to the principles of gait biomechanics. The regulation (position change) is performed by the physiotherapist at the temporary mechanical (regulation) levels of the prosthesis (Picture 5 a-c). This phase requires from the physiotherapist a detailed analysis of patient's posture with the prosthesis on, during stance and gait. For example, incorrect position of prosthesis' foot towards valgity or varus deformation or its excessive dorsal or plantar flexion in patients with trans-tibial amputation would disturb knee joint mechanics (Picture 6). In case of a persistent contracture (e.g. in case of flexion contracture in the knee joint), applying the funnel of temporary prosthesis at an appropriate inclination angle as well as proper regulation allow obtaining its optimal position. This phase of prosthesis fitting determines correct, as physiological as possible, patient's gait and hence the comfort of prosthesis use. The process of prosthesis regulation may last several to twenty days, including the whole period of its adjustment and all stages of patient's locomotion with the prosthesis. It should be born in mind that the status of patient's stump (skin reddening, presence of abrasions, cyanotic skin) should absolutely be checked after each removal of the prosthesis[19].



Picture 5 a-c

Prostheses during the adjustment phase. Regulation level of a below-knee prosthesis (a, b). Regulation level of an above-knee prosthesis (with permission from the Artificial Limb Centre (CRA – Centre de Reeducation et d'Appareillage), Institut Robert Merle d'Aubigne, Valenton, Ile-de-France)



Picture 6

The most frequently used foot with a replaceable rubber dumper (its hardness is adjusted to patient's weight). The patient can regulate himself the inclination angle of the dorsal and plantar flexion of the foot as needed (adjustment to the heel's height of the used shoes) (with permission from the Artificial Limb Centre (CRA – Centre de Reeducation et d'Appareillage), Institut Robert Merle d'Aubigne, Valenton, Ile-de-France)

The temporary prosthesis is subjected to multiple necessary modifications. Concurrently, during the whole adaptation and modification period, it serves the patient in learning to move, which is why it is also referred to as "training prosthesis". During the prosthesis regulation phase, the patient is allowed to move with the prosthesis, but only under physiotherapist's supervision and only within the rehabilitation centre, as particular prosthesis' elements are not definitively connected with each other, which is associated with a threat of its derangement at excessive loading and a threat of fall.

Reduction of patient's stump circumference due to gradual subsidence of post-surgery oedema results in a situation, where the funnel of the temporary prosthesis becomes too large. Such changes in stump dimensions with regard to the funnel size are compensated for by putting one or – when needed – several cotton stockings on the stump. Conversely, when a substantial change in stump size occurs, as compared to baseline dimensions, a new prosthesis funnel should be made.

After the patient is through with the initial period of temporary prosthesis adaptation and after the process of alterations of the shape and size of the stump is markedly slowed and prosthesis regulation is completed, fabrication of the definitive prosthesis is initiated. For this purpose, the physiotherapist prepares a plaster cast of the stump again and has it filled with plaster to obtain the stump positive model, which is subsequently modified (in the same way as by the production of the temporary prosthesis). When finished, the positive model is sent to the cooperating prosthetic department, and the chosen type of the funnel (most frequently made of plastic or carbon fibre) and the foot (for very active persons or athletes – a type of dynamic foot ensuring higher movement springiness) as well as the remaining necessary components of the prosthesis are simultaneously ordered. Assembly of these elements is conducted in the rehabilitation centre, and the appropriate regulation of the prosthesis is performed by the physiotherapist, as with the adjustment of the temporary prosthesis. After the regulation has been finished, the prosthesis is delivered to the technicians, who assemble permanently and fix its elements, and is subsequently sent again to the prosthetic department for finishing.

The prosthesis should possibly best resemble patient's healthy extremity in shape, colour and appearance. For its aesthetic finishing, measurements of circumferences of the other limb are taken, and an appropriate colour of the coating, corresponding to patient's skin colour, is chosen. There is also a possibility of achieving a hair effect, with hair density like that of the contralateral limb (thanks to which males can wear shorts).

Patients, who already started to walk with the definitive prosthesis, are allowed to spend a week-end at their homes and to participate in integration activities organised periodically by the centre and supervised by physical education instructors, physiotherapists and nurses.

In patients after below-knee amputations, contact prostheses with a subpatellar support are most often used, whereas in patients after above-knee amputations, negative pressure prostheses with a fixed knee link (for the elderly or the weaker persons) with a lock (enabling flexing the link e.g. in the sitting position) or with a mobile link are most frequently fitted. The knee link should offer a compromise between full stability during the support phase and controlled mobility in the translocation phase of the gait[20]. A controlled link with built-in microprocessor is an example of a mobile knee link enabling nearly physiological locomotion on different surfaces and at various conditions. Such link is primarily recommended for active and dynamic persons. A prosthesis containing such type of link allows the amputee to rapidly change step length or gait velocity without excessive concentration on this activity.

Prostheses are composed of individually chosen elements (this refers to various combinations of links between particular prosthesis components: the funnel, the knee link, shin and foot elements) and materials (e.g. funnels made of plastic, carbon fibre, silicone, or –in some patients previously repeatedly fitted with prostheses – of wood) depending on patient's needs, fitness, age, weight, efficiency, type of occupation and sport activity. Prosthesis finishing can also be different (material and colour).

Persons with unhealed stump and without a possibility of its distal loading may take first steps very early thanks to a prosthesis of a "monobloc" type (Picture 7 a and b). In the majority of cases, this is a form of temporary prosthesis made of plastic. It should be added that this prosthesis type also enables rapid initiation of walking in the amputees with skin transplantations (e.g. after amputations due to trauma-related causes). An aperture-window is cut in the prosthesis funnel at the level of skin lobe attachment for this purpose; owing to this "procedure", the patient does not compress the sensitive and healing region of the residual limb.

Picture 7 a i b

The "monobloc"-type prosthesis enabling the persons with an unhealed stump to take the first steps very early and without loading the distal part of the stump (with permission from the Artificial Limb Centre (CRA – Centre de Reeducation et d'Appareillage), Institut Robert Merle d'Aubigne, Valenton, Ile-de-France)

Shape of the stump and its correct positioning

It is important that the stump has an optimal shape for the prosthesis. The form of the stump undergoes constant changes throughout the whole patient's life. Gradually decreasing post-operation oedema significantly changes stump parameters within a short period of time. These parameters also depend on patient's care for his own extremity, the way of its positioning at rest (Figure 2), degree of amputee's physical activity and – primarily – on the bandaging.

Sometimes, following discharge from the rehabilitation centre, after receiving the prosthesis, completing the rehabilitation programme and a relatively short stay at home, patients contact their kinesitherapist asking for assistance because applying the prosthesis (previously well fitted) becomes impossible. After obtaining complete information on the management at home, it most frequently turns out that the patient does not care for his stump ceasing to bandage it (despite the instructions prior to the discharge home), which increases the oedema. In such situation, several patient's visits in the centre may have a good effect. During the visits, the amputee is placed in bed in the supine position with elevated (supported) and relatively tightly bandaged (with proximally decreasing pressure force) stump, positioned at an angle of 45 degrees for a period of 20–30 minutes per day. After several days of such procedures, it is usually possible to effectively reduce the oedema and reapply the prosthesis.

The shape of the stump also depends on the amputation level (degree of damage to the muscles and their length left over), as well as on the amputation cause (e.g. in case of post-traumatic amputation, possibilities of achieving an optimal stump shape for the prosthesis are limited). For instance, if the shank stump is long, markedly irregular and markedly bulb-shaped, a prosthesis funnel combined of two detachable elongated shells (anterior and posterior) may be used, which enables application of the prosthesis (Picture 8 a-c).

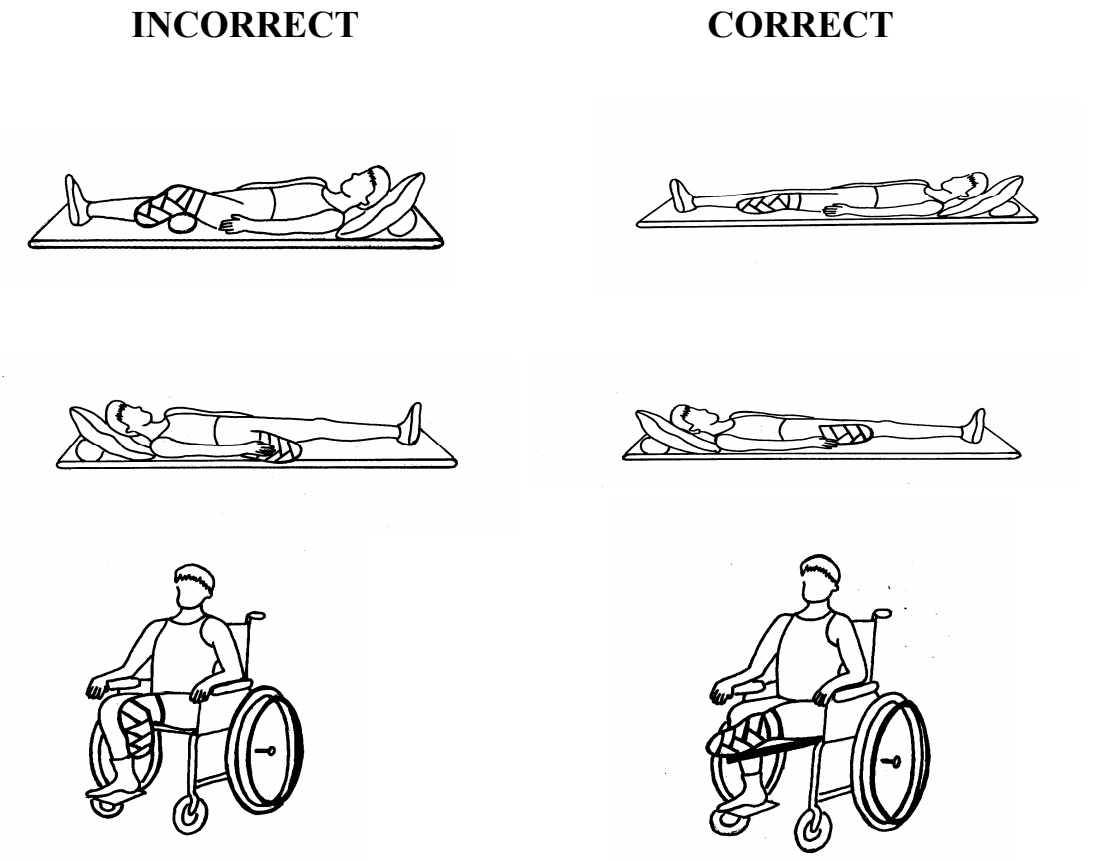


Figure 2

Incorrect (a, b, c) and correct (d, e, f) positioning if the stump. Incorrect: positioning the stump with a pillow under the knee (a); positioning of the stump at abduction (b); maintenance of the knee in flexion in the sitting position (c). Correct: positioning of the lower residual limb with extension in the knee joint (d); positioning of the thigh stump at adduction (e); maintenance of the knee in extension in the sitting position using a calf support (f).

If the shank stump is less irregular. with insignificantly increased circumference of the distal part, the prosthesis funnel may be appropriately modified by a longitudinal cut on its posterioir part and application of a ski-type fastening (used to buckle up ski-boots) (Picture 9). In this way, the patient may put on the prosthesis by delicately parting the upper cut part of the funnel that is subsequently compressed by the buckle.

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Picture 8 a-c

The stump after the Pirogov-type operation (posttraumatic aetiology, a patient after a traffic accident), closed with the prepared skin lobe taken from the patient's heel – difficult to fit with the prosthesis (a). The prosthesis during fabrication with a carbon fibre funnel (the prosthesis funnel combined of two detachable elongated shells: anterior and posterior) (b), and the patient fitting on the prosthesis (c) (with permission from the Artificial Limb Centre (CRA – Centre de Reeducation et d'Appareillage), Institut Robert Merle d'Aubigne, Valenton, Ile-de-France)

Proper positions of the stump are also extremely important in contracture prevention in the joints of the residual extremity and to combat the already existing contractures. Lower limb contractures are a common complication in the amputees. Unfortunately, the positions comfortable for the patient concomitantly favour contractures[19]. According to Wasiak[9], the main cause of contractures formation in vascular diseases is prolonged pain forcing the patient to assume constrained positions, usually with flexion in the hip and knee joints. Also, scarring in the popliteal fossa, for example after femoro-popliteal grafts, is not unimportant as a contributing factor[9].

Picture 9

Temporary prosthesis of the shank with the ski-boot type buckle (with permission from the Artificial Limb Centre (CRA – Centre de Reeducation et d'Appareillage), Institut Robert Merle d'Aubigne, Valenton, Ile-de-France)

In trans-femoral amputees, contractures in the hip joint, of abductors and rotators, frequently develop, whereas in trans-tibial amputees, contractures of hip and knee flexors can occur. Contractures of hip and knee flexors usually result from patient's frequent remaining in the supine position (additionally, with a pillow placed under the stump). To avoid contractures, the amputees are instructed to frequently move the limb, preferably in a full range of motion[19]. Disturbances in the muscular equilibrium of antagonistic muscle groups occurring after the amputation are primarily postulated as a cause of contractures development. Consequently, in amputations at the level of the thigh, there is a predominance of flexors, abductors and external rotators, while in amputations within the shank – flexor muscles predominate. Patients staying in the comprehensive rehabilitation centre with a trans-tibial amputation, from the first day on, use wheelchairs with a special, mandatory support under the stump in order to maintain the knee joint in extension as often as possible during the day.

Rehabilitation

Gait learning

From the very beginning, while awaiting the prosthesis fitting, the amputee prepares for its adaptation. If his general condition allows it, attempts to assume a vertical position should be started as early as in the first day of hospitalisation, although the patient usually arrives from the hospital with an initial ability of locomotion. If orthostasis is initiated as late as after the admission to the centre, it is initially practiced between handrails in the room for march learning. The first task involves learning of rising safely from the wheelchair, which also constitutes a form of balance exercise. Then, gait learning between handrails using one leg and learning to turn is introduced. The next stage involves walking using one leg in a walker and subsequently with crutches. Patient's greatest possible independence is aimed at since the first days of his stay in the centre. The amputees move independently on wheelchairs. To facilitate patient's orientation and independent locomotion within the centre, the building's interiors are designed in such a way that walls of particular wards are painted with different colours.

After the first fitting of the temporary prosthesis and its proper adjustment, learning to walk between handrails and subsequently with a walker (analogically to the order of earlier stages of gait learning without the prosthesis) is started. When the level of stable locomotion with crutches is already achieved, walking with one crutch, then with a stick, and – when possible – without any assistance, is attempted. The patient learns to walk on a stairway (walking up and down the steps is more difficult for patients with trans-femoral amputation, who move using a prosthesis with a mobile knee link), to overcome obstacles (e.g. medicine balls or crutches lying on the floor) and uneven ground, and learns to get on and off the moving track (which simulates walking on escalators and moving pavements) under careful supervision of the physiotherapist working with the patient (always with his assistance). On the moving track (operating in two directions, with optional change of the inclination angle), it is also possible to practice walking up and down. Finally, only integration with the external environment and sport activity remain to be introduced.

Relatively rarely, the patient cannot start learning to walk with the prosthesis due to e.g. hypersensitivity of the stump to pressure and severe pain occurring during the contact with the prosthesis; however, in such a situation, the treatment is started with a procedure of gradually bringing the patient to the vertical position with the prosthesis on, using a tilt-table. Walking sessions are conducted twice a day.

The advantage of patient treatment in a comprehensive rehabilitation centre is a possibility of continuous and immediate assistance of the physiotherapist during all sessions of gait learning with the prosthesis and during the conducted sport activities or integration trips. In case of occurrence of any faults, e.g. deregulation of prosthesis elements, problems are immediately corrected or removed. Thereby, a possible situation is avoided, where the amputee would receive the temporary prosthesis as an outpatient and then, after a single check-up and regulation, would learn to walk in it without assistance.

Kinesitherapy and physiotherapy

Each amputee has to wait at least up to twenty days for the initiation of prosthesis fitting, whereas the comprehensive rehabilitation is provided from the first possible point of time. The rehabilitation programme comprises: individual exercises conducted in the rehabilitation room, aiming at combating and preventing contractures, reinforcing the muscles and thus accelerating the process of stump healing by stimulating the circulation. In patients with lower limb amputation, except from exercises reinforcing the muscles of the lower extremity, increasing muscle strength of the upper extremities is equally important, as they constitute the basis of smooth locomotion using the wheelchair, transfer from one place to another (e.g from the bed onto the wheelchair), walking using a walker or crutches[19]. Patients additionally perform mobilisation exercises in bed, including rolling from one side onto the other and sitting up (learning to change the position independently), balance exercises using a ladder and performed on a ball, moving platform or a bounce-board, general physical exercises and transfer exercises (wheelchair-bed). The ability of independent transfer from bed onto the wheelchair makes it possible for the patient to "broaden his own world beyond the bed and room"[19].

Procedures of physical therapy are also used, primarily TENS currents and ultrasounds. It was proven that transcutaneous electrical nerve stimulation is an effective physical method of controlling the phantom pain, and the percentage of positive responses to the treatment ranges 45% to 65%[16]. Physical therapy is also used in cases of concomitant diseases, such as e.g. degenerative diseases of the joints. It must not be forgotten that the stump pain may be induced not only by the pressure exerted by the funnel, but also a degenerative disease (e.g. gonarthrosis).

Ergotherapy

Patients with additional dysfunction of the upper limbs movement should also participate in ergotherapy exercises. It is a form of therapy helping the patient to reinforce or regain his own social autonomy. To achieve this, the patient practices activities of daily living, i.e. preparing meals, ironing, dressing-up (buttoning, zip-fly use), doing recreational works (e.g. embroidering, doing puzzles), performing household repair jobs. Additionally, in cases of severe motor dysfunction of the hand, the ergotherapist prepares necessary aids for the patient, e.g. modifies and adjusts the handle of a fork, spoon and knife for a person with concomitant advanced rheumatic changes in the upper limb being unable to hold the cutlery in hand. The ergotherapist also informs the patient about necessary, available for purchase devices and conveniences that will facilitate many every-day activities.

Psychological support

The psychological aspect is important as well. Beginning with the first moment of stay in the comprehensive rehabilitation centre, patients are provided with help of an experienced psychologist. Sessions with the psychologist can have a form of individual or group therapy (e.g. support groups).

Integration with every-day life environment

Patients hospitalised in the department being sufficiently fit, moving using definitive prostheses, dependently on attending physician's decision, are transferred weekly to their homes for the whole week-end to gradually get used to every-day household activities and thus examine their abilities of independent locomotion with the prosthesis outside the rehabilitation centre. Owing to such trials, they can improve their skills after returning to the centre, being aware of the direction of their needs.

One of the assumptions of functioning of a comprehensive rehabilitation centre is not only restoration of patient's optimal abilities following prosthesis fitting, enabling a rapid return to every-day life, but also continuous aug-

mentation of patient's physical possibilities and improving general condition of the whole organism. For this purpose, patients participate in a series of motor activities, i.e. tennis, badminton, table tennis, climbing on a custom-designed artificial wall, archery, *petanque*[2], training in a fitness room, swimming, diving, water ball, kayaking (in the swimming pool) and team games: volleyball, basketball. Only patients with completely healed stump are allowed to participate in the swimming pool activities. Aside from swimming, various water exercises are used and kayaking is taught, which substantially expands the sensation of balance of the amputees who have disturbed body symmetry.

Sport activities create a possibility of full prosthesis testing and a profound recognition of the new body structure (balance sensation, movement dynamics). Some patients do additional forms of motion, most frequently – jogging. This form of activity is possible with the use of dynamic prosthesis with a soft silicone insert inside the funnel (preferably made of carbon) and a dynamic foot.

Sautreuil et al.[21] emphasise that lower limb amputation in young and middle-aged persons does not mean that his sport activity ends. Conversely, some amputees compensate for their motor deficits and achieve exceptional results e.g. in running. A sport club for the amputees is also active in the centre, lead by physical education instructors and physiotherapists that organises afternoon training meetings for former patients of the centre. The meetings are attended by young and middle-aged patients, whose general health status allows intensive physical effort during advanced sport activities. Permission for this form of activity is given by the physician. Some of these persons have a chance to prepare in this way for the competitions for amputees. For former patients of the centre, the sport club organises several-day recreational-sport trips to various places in France several times a year, where the participants do such sports and recreation forms as: hiking, cycling, alpine skiing, cross-country skiing, kayaking, sailing, rock climbing, high-mountain climbing, swimming or diving.

At the time of the planned discharge home, the ergotherapist visits together with the patient his house to check amputee's habitation conditions. The following features are evaluated: safety of locomotion and possibility of smooth moving in particular rooms, conditions of bathroom (presence of necessary handles, bath chairs, conveniences) and kitchen (ergonomics and safety) use, as well as door-frame width that should enable unproblematic transferring using the wheelchair. If significant obstacles that could interfere with patient's life are identified, the ergotherapist advices the amputee on proper modifications and finds appropriate institutions that may help in adopting the flat to the current needs. Ergotherapist's tasks also include the arrangement of all necessary formalities associated with the purchase of the amputee-adjusted car.

Influence of concomitant diseases on the rehabilitation process

Concomitant diseases are also taken into account when planning the rehabilitation programme with regard to the type and intensity of the therapy, as they may significantly influence both the process of prosthesis fitting and the rehabilitation. In some cases, aggravating symptoms of coexisting diseases require withdrawal of the rehabilitation and even repeated hospitalisation of the patient.

Among the concomitant diseases of the amputees, the following are most frequent: arterial hypertension, diabetes mellitus and its complications (nephropathy, retinopathy, cardiomyopathy, arteriopathy, necrosis of the toes), polyarthritis, past pulmonary embolism, heart infarction, thrombophlebitis, allergies (prosthesis funnel or insert intolerance), painful shoulder syndrome (frequently occurring in the amputees due to diabetes[22]), psychoorganic syndrome, gonarthrosis, hyperlipidaemia, states of acute limb ischaemia, a history of previous coronary artery (CABG) or peripheral lower limb arteries by-pass grafting, angioplasty, post-amputation complications (exostoses), cataract, vision disturbances, atherosclerosis, Buerger's disease, lower limbs paresis or plegia[23,24,25]. These conditions require special adjustment of the rehabilitation programme, also considering the application of physical therapy procedures (e.g. in cases of degenerative diseases of the joints).

Special treatment is required by patients after vascular amputations with coexisting cardiovascular diseases, in whom walking with the prosthesis creates additional burden (increases energy expenditure, especially in trans-femoral amputations at a high level, and – the more so – in bilateral amputations).

Many concomitant diseases also require expanded ergotherapy. This particularly refers to patients with disorders involving especially the motor function (neurological and rheumatic disorders, or post-traumatic states).

Sometimes, the patient has to return to the hospital ward because of the worsening health status, poorly healing stump or a necessity of re-amputation.

[2] *Petanque* – a traditional French game using balls – author's footnote

Case report of a patient with long-term stump healing

An 80-year old man after left shank amputation due to advanced diabetic changes in the left foot (29.10.2003), with years-long course of diabetes mellitus, with symptoms of depressive syndrome, was admitted to a comprehensive rehabilitation centre – the Centre for Rehabilitation and Prosthesis Fitting (CRA – Centre de Reeducation et d'Appareillage) at the Institut Robert Merle d'Aubigne in Valenton / located in the Ile – de – France region, on 12.11.2003.

The preserved stump had an optimal length for prosthesis fitting, was unhealed, with sutures left. There were diabetic changes in the right foot (appropriate orthopaedic shoes had to be made because of the sensitive foot). Due to emotional lability and depressive states, the patient was offered psychologist's help.

Nineteen days after the amputation, the stump was still sensitive to touch, the post-operation sutures were left. Continuation of every-day dressings was recommended (in cases of dripping from the post-operation wound – even several times a day). Measure was taken for the orthopaedic shoe for the right foot. Active exercises of flexion and extension in the knee joint of the affected limb were introduced to prevent contracture and reinforce muscle strength (of the quadriceps femoris). Upright posture training between handrails with loading of the right lower limb was initiated.

Twenty six days after the amputation, paroxysmal tachycardia occurred twice, due to which all rehabilitation procedures were withdrawn on this day. Further care of the poorly healing stump was recommended before starting the prosthesis fitting. On the following day, handrails-assisted trials of assuming the erect posture and active exercises of the stump were resumed.

Thirty three days after the amputation, the patient was in good general condition and fitting of the temporary prosthesis was initiated. The patient received the made to measure orthopaedic shoe, thanks to which he could move on one limb gradually increasing walking distance; before that time, he had performed brief practices of maintaining the upright posture and marching between handrails (several steps and exercises of knee extension in order to strengthen the muscles and to prevent contractures).

Forty days after the amputation, post-operation sutures were removed. Stump circumference and length measures were taken for the preparation of temporary prosthesis. The stump was still not completely healed.

Sixty eight days after the amputation, the patient received the temporary prosthesis and made first, careful (because of the still poorly healing post-operation wound of the stump) attempts of standing and walking between handrails. As a result of loading the stump with the prosthesis, dripping from the post-operation wound was augmented, which caused withdrawal of patient's participation in the afternoon session of rehabilitation exercises. During the next two days, rehabilitation procedures were restricted to exercises, while upright posture training with the prosthesis was resigned on. On the following day, after an improvement had been observed, the rehabilitation procedures performed hitherto were reintroduced and expanded with new elements (increasing walking distance between handrails). In the later course, similar complications never recurred. Stump care was continued (dressing of the wound).

Seventy five days after the amputation, the patient was able to move in the temporary prosthesis using a walker. An improvement of the amputee's emotional state was observed, which likely resulted from the awareness of the progress made by the patient in learning to walk.

Seven days later, the stump was almost healed and the patient was making a rapid progress in gait learning. Definitive prosthesis fitting was started.

Eighty nine days after the amputation, the patient began gait learning in the definitive prosthesis using elbow crutches.

Ninety six days after the amputation, the stump was completely healed. The definitive prosthesis underwent further adjustment and modification (definitive assembly, finishing). The date of patient's discharge from the centre was anticipated (in 14 days, that is 110 days after the amputation).

After leaving the rehabilitation centre, within a short period of time spent at home (approximately 10 days), the patient contacted his physiotherapist asking for help, as application of the prosthesis, previously well fitted, became impossible. After full information related to the management at home had been obtained, it was stated that the stump was improperly cared for due to withdrawal of bandaging, despite the instructions given prior to patient's discharge, which induced stump oedema increase. In these circumstances, patient's several, every-day visits in the centre were effective. The amputee was positioned in bed in the supine position with stump (supported) elevation and relatively tight bandaging (with proximally decreasing pressure) at an angle of 45 degrees for a period of 20–30 minutes. After several days of such procedures, oedema was successfully reduced and the prosthesis could be reapplied.

After the rehabilitation procedures were completed, the patient was scheduled for a follow-up visit in two weeks.

Summary

The presented model of comprehensive rehabilitation appears to be the appropriate mode of management of patients after lower limb amputations. Its advantages include: ensuring the continuity of rehabilitation procedures (the amputee is referred to the rehabilitation centre directly after the hospitalisation in the surgical ward), relatively rapid prosthesis fitting (frequently as early as in the 3rd week after the amputation), comprehensive control of patient's state, e.g. caring for skin hygiene of diabetic patients by providing pedicure service. Professional psychological assistance offered from the first days of stay, especially important during the first weeks following the amputation, optimal preparation of the patient to social life (in a relatively short period of time), a possibility of permanent observation of the amputee and his prosthesis and of immediate professional intervention if problems associated with the prosthesis occur, as well as a possibility of participation in facultative sport activities offer the patients a new goal of life, while they simultaneously continue to improve their physical fitness. This enables integration with other amputees, which reduces patients' undermining their self-esteem and helps in a better adjustment to the new situation in their lives. The amputee walking in the definitive prosthesis can take the advantage of week-end trips home while still being the patient of the centre and – owing to such trials – has a possibility of noticing any possible problems associated with moving at home.

Additional advantage of the comprehensive approach is a possibility to obtain ergotherapist's help in the preparation of necessary devices facilitating activities of daily living as well as to take his advice on the adjustment of patient's household conditions.

In this article, usefulness of certain prosthetic procedures undertaken additionally by the physiotherapists was emphasised. The advantage of such system involves immediate participation of the physiotherapist in all the most important stages of the prosthesis fabrication process, and thus a better comprehension of its structcure enabling immediate intervention in case of any prosthesis-associated problems, as well as a possibility of rapid prosthesis improvement if any abnormalities in patient's gait are noticed.

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